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(54) Purifying liquids by distillation

(57) In a distillation process for purifying a liquid (e.g. seawater) stored in a reservoir, the liquid is heated by solar energy and evaporated in an evaporator, the resultant vapour is condensed and the unevaporated liquid is returned from the evaporator to the reservoir. In one embodiment, seawater which has been heated by solar energy is transferred from lagoon 10 to a vacuum boiler 30, steam being delivered through a turbine 54 to a condenser 22. The turbine generates the power necessary for the running of the apparatus. Pure water is collected from the condenser and the seawater remaining in the boiler is returned to the lagoon through pipe 38 and flexible tubes (not shown) arranged on a terraced support 12 sloping down to the lagoon, the tubes defining a collector for solar energy. The salinity balance in the seawater returned from the boiler is maintained continuously by a flow circuit so arranged as to require no additional power consumption.

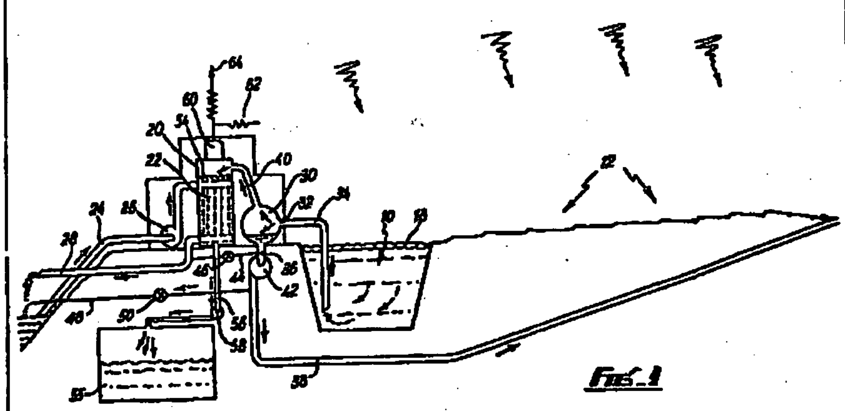

FIG. 1

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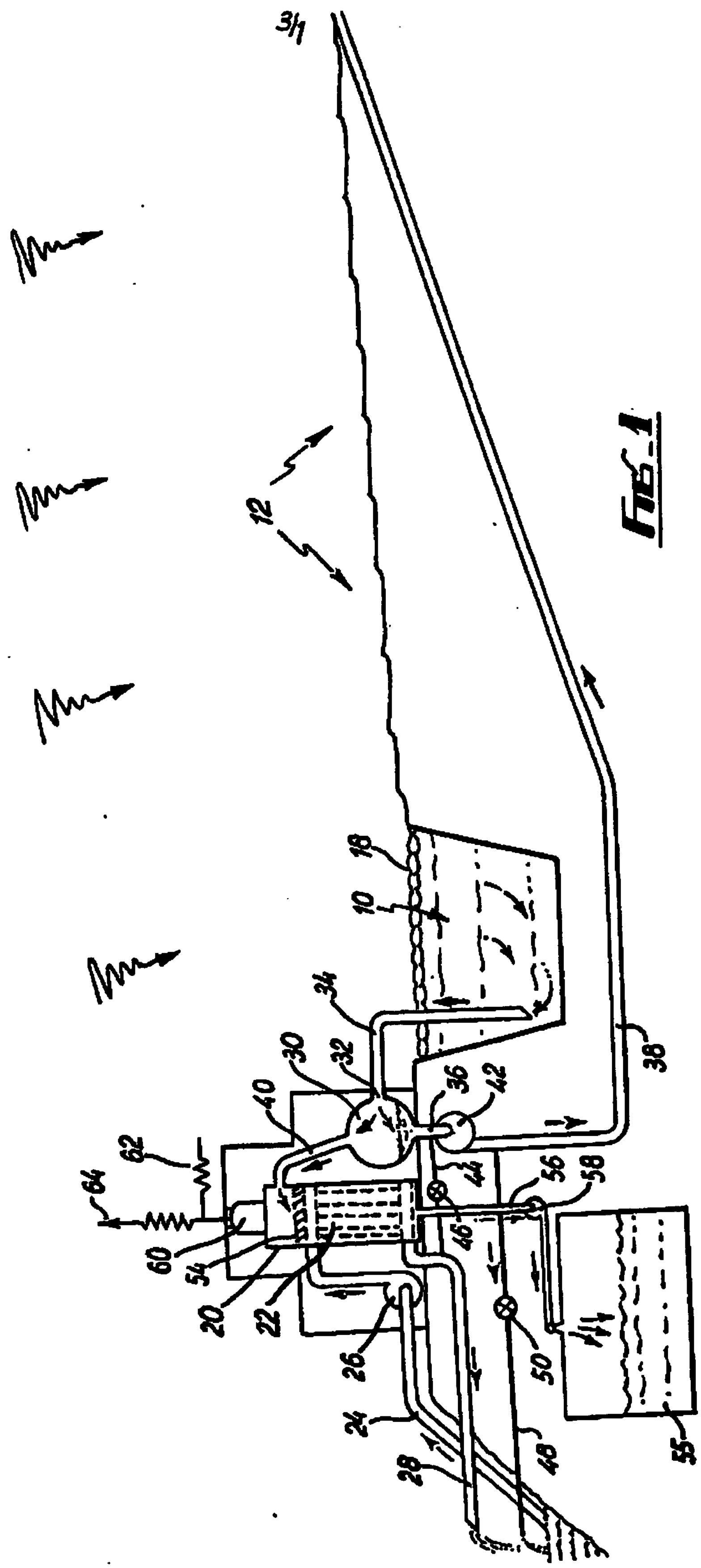
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FIG_1

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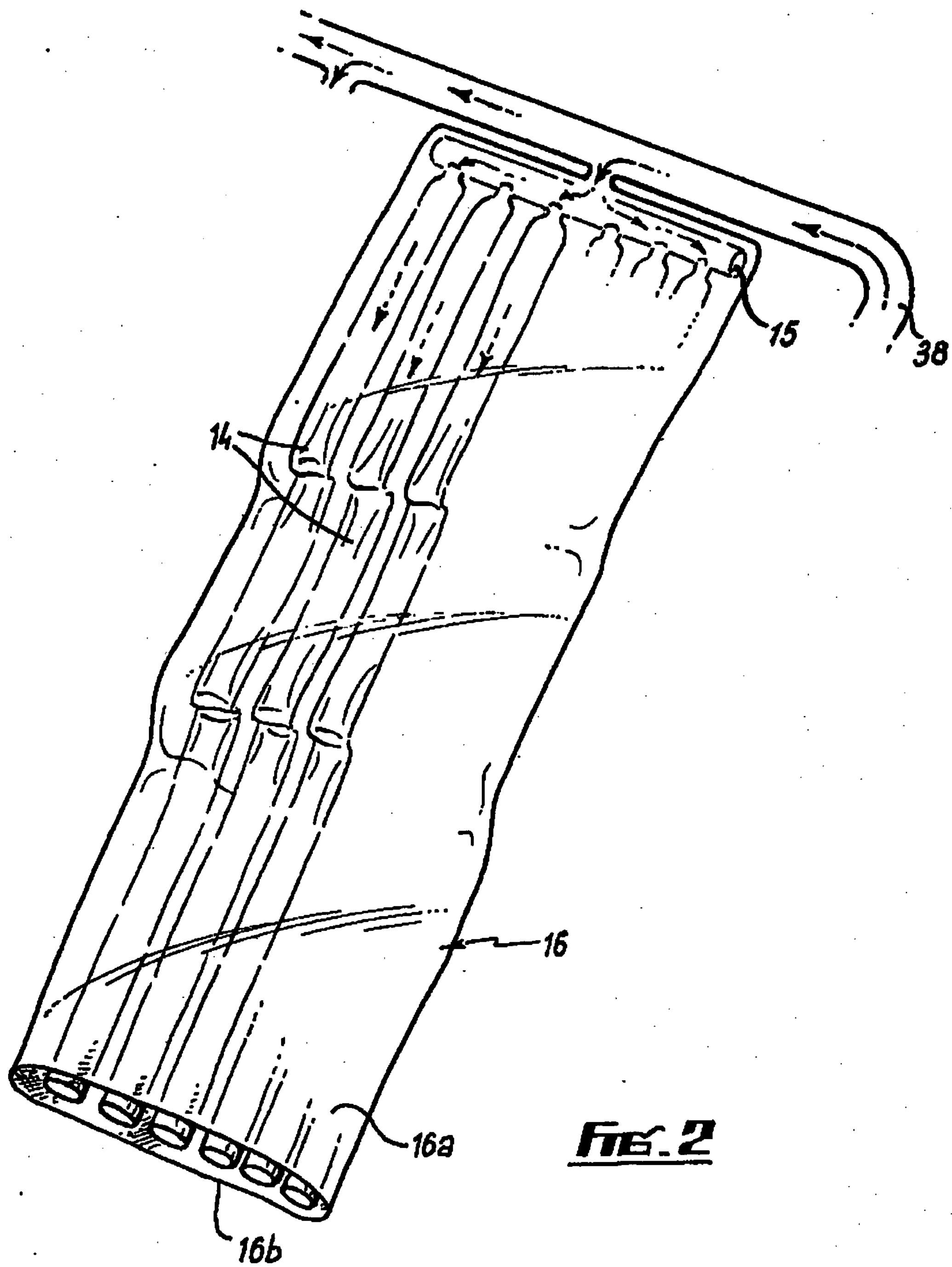

FIG. 2

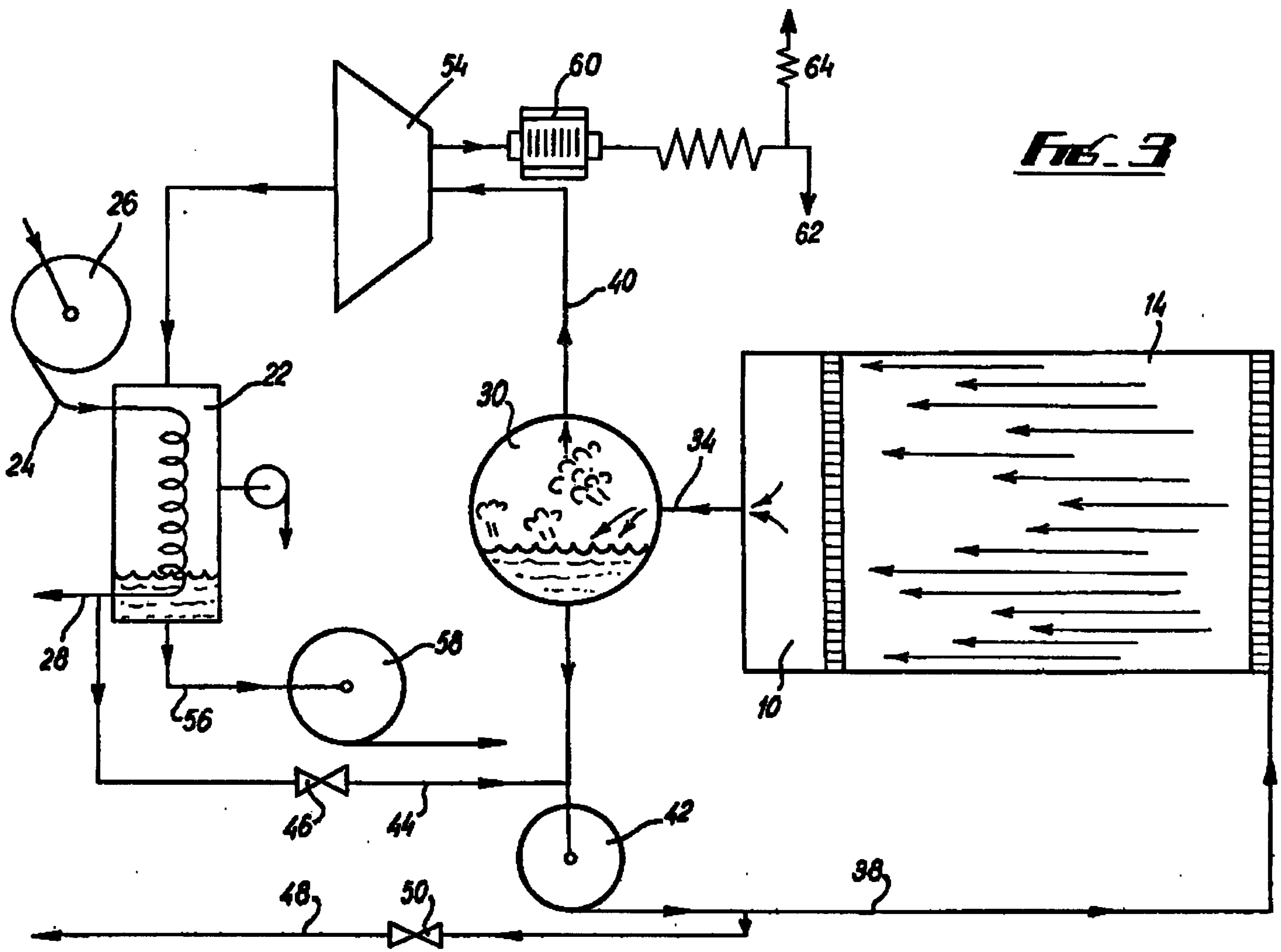

FIG_3

SPECIFICATION

Improvements in or relating to desalination apparatus and method

This invention relates to a method of, and apparatus for the separation of water or other liquids from chemical or solid organic matter therein. For ease of description reference will be made hereinafter to only one main application of the apparatus, i.e. the desalination of seawater.

The provision of fresh water is a problem in many countries in particular desert countries, where rainfall is scarce and there is a lack of rivers or other water sources. Attempts have been made to provide water by the desalination of seawater, to which many of such countries have ready access but conventional desalination plants which could operate on a scale sufficient for the purpose of providing water for drinking, irrigation etc. are extremely costly both to install and maintain, requiring a considerable input of power for running of the plant.

According to the present invention there is provided apparatus for use in the desalination of seawater, said apparatus comprises means for transferring seawater from a reservoir arrangement, effecting evaporation of the seawater, and passing the evaporated water to heat exchange means so as to effect condensation of the evaporated water, and means for delivering seawater remaining in the evaporating means into the reservoir arrangement for heating therein by solar energy.

Preferably the apparatus includes means for continuously maintaining the salinity balance in the seawater delivered into the reservoir arrangement, which means comprises a flow circuit defined by first conduit means connected between an outlet of the heat exchange means and an upstream side of a pump provided for removing the seawater remaining in the evaporating means, and second conduit means connected between the downstream side of the pump and an outlet, means being provided in each conduit means for controlling flow of seawater therein in accordance with the rate of evaporation, such that the salinity balance is maintained without any additional power consumption.

Preferably also the means for delivering seawater into the reservoir arrangement comprises a flow arrangement for collecting solar energy, the flow arrangement comprising elongate flexible conduit means arranged to be located on a terraced support surface which slopes in a direction towards the reservoir arrangement, at least the surface of the conduit means arranged to be adjacent to the support surface having heat absorbing properties.

An embodiment of the present invention will now be described by way of example only with reference to the accompanying drawings in which:-

Figure 1 is a schematic representation of an apparatus according to the invention;

Figure 2 is a schematic representation of a flow arrangement of the apparatus of figure 1; and

Figure 3 is a flow circuit diagram of the apparatus of Figures 1 and 2.

Referring to the drawings, a desalination apparatus is arranged to be erected particularly on a coastal strip of a desert area and requires an initial excavation of the area. A reservoir for seawater in the form of a lagoon 10 is formed in a known way at a location inland, and further inland of the lagoon 10, the ground is formed in a terraced fashion having a series of horizontal terrace areas 12 increasing steeply in height in a direction away from the lagoon 10. Each area 12 has a backfall against the direction of the slope.

The terraced area is covered by conduit means in the form of tubular elements 14 (Figure 2) of a dense black flexible plastics material, for example polythene, independent of one another, but arranged, for ease of handling, in batches. Each tube 14 is connected at the upper end of the terraced area to an outlet of a distribution manifold 15 and the tubes 14 and manifold 15 are located within a main tubular member 16. The latter is formed in two parts 16a, 16b releasably joined together, the lower part 16a, on which the tubes 14 lie on the terraced area, being formed of a dense black flexible plastics material and the upper part 16b being formed of a transparent, ultra-violet inhibited flexible plastics material. The terraced nature of the ground causes the tubes 14 to deform when passing from one area 12 to another, which constricts the flow through the tubes to maintain them in a full condition and also improves agitation of the water. The back fall maintains the tubes 14 in a half full condition if the system is non-operative. The lagoon 10 is covered with a transparent bubbles plastics material 18 which reduces heat loss by re-radiation, wind effect and evaporation. The member 16 also reduces heat loss by re-radiation and wind effect and protects the tubes 14 against ultra-violet degradation.

Between the lagoon 10 and the sea there is provided in a housing 20, a heat exchanger 22 which has an inlet pipe 24 leading from the sea and incorporating a pump 26, and an outlet pipe 28 which also leads into the sea. At one side of the housing 20 there is provided a vacuum boiler 30, which has an inlet 32 communicating by means of a pipe 34 with the seawater in the lagoon 10 and a drain outlet 36 leading into a delivery pipe 38 for a purpose hereinafter described. The boiler 30 has a steam outlet 40 communicating with the upper end of the housing 20 such that the steam is subjected to limited travel between the boiler 30 and the housing 20.

The delivery pipe 38 extends to the uphill end of the tubes 14 and water is pumped from the boiler 30 to the manifold by means of a pump 42. Upstream of the pump 42 a first conduit or pipe 44 of an arrangement for continuously maintaining a salinity balance in the apparatus connects the delivery pipe 38 with the heat exchanger outlet 28 through a flow control valve 46. Downstream of the pump 42 a second conduit or outlet pipe 48 connects with the delivery pipe 38 through a flow control valve 50.

The condensate in the housing 20 can be removed to a store 55 by means of a pipe 56 provided with a pump 58.

It may also be preferable to include a pump in the pipe 34 to assist in drawing seawater from the

lagoon 10 and to provide a further pump operated by a vaccum switch in the housing 20 so as to remove any build-up of non-condensables in the seawater.

Further, power generating means in the form of a turbine 54 is located at the upper end of the housing 20 in the path of the steam from the boiler 30, such that passage of the steam through the turbine can, by virtue of a generator 60, generate power which can then be utilised to operate the various pumps in the apparatus via an output 62 and provide any surplus electricity at an output 64.

In use, the vacuum applied to the boiler 30 draws in seawater through the pipe 34 via a flow control valve, the heating of the seawater by solar energy enabling flash boiling to take place. The steam produced then passes into the housing 20 through the turbine 54 and condenses on the heat exchanger 22.

During day time hours the seawater in the lagoon 10 is heated by solar energy, and the seawater which drains from the boiler 30 into the delivery pipe 38 is passed to the tubes 14 to absorb solar energy when flowing into the lagoon 10. The arrangement of the tubes 14 is designed to be 2.4 times the size required to operate during day time hours so as to accommodate energy loss at night. The apparatus can then operate for 24 hours each day. Alternatively during the night the seawater in this pipe 38 may be diverted through a bypass pipe (not shown) directly into the lagoon 10.

The arrangement for continuously maintaining the salinity balance operates without any power consumption additional to that necessary for normal operation of the desalination apparatus. This can be achieved because the inlet end of the pipe 44 is at least atmospheric pressure while the other end of the pipe 44 is at the pressure at which flash boiling takes place, this being a convenient constant substmospheric pressure. The flow of the seawater into the delivery pipe 38 is thus effected. As the pump 42 is required to raise the seawater to the level of the lagoon 10 which will be not less than 20 feet above sea level, this head of water, in addition to the pipe friction which is at a maximum at the downstream side of the pump 42, creates a pressure at the inlet end of the pipe 48 greater than the pressure at the other end of the pipe 48, which is atmospheric. Thus flow through the pipe 48 is effected. The flow control valves 46, 50 are controlled by the turbine 54, the operation of which is of course dependent on the rate of evaporation i.e., the flow of the dry saturated steam from the flash boiler.

To enable the salinity level in the lagoon 10 to be maintained at a predetermined multiple of the normal salinity level in the available seawater which is drawn in through the pipe 44, the flow rate in the latter is adjusted to be that predetermined multiple of the flow rate of the dry saturated steam from the boiler 30, the flow rate in the pipe 48 being adjusted to be the same as the flow rate of the dry saturated steam. By way of example, if 100 lb/min of dry saturated steam is desired this will determine the required flow of seawater from the lagoon 10 to the boiler 30, and if the desired salinity level is to be twice that of the normal salinity level (assumed to be 5%), then this will require a flow rate of 1000 lb/min of seawater containing 100 lbs of salt through the lagoon 10 into the boiler 30. The removal of the steam in the latter provides a flow rate of the seawater remaining in the boiler 30 of 900 lbs/min still with 100 lbs. of salt. Added to this through the pipe 44 is 200 lbs/min of seawater containing 10 lbs of salt (5%) creating a total flow to the pump 42 of 1100 lbs/min of seawater containing 110 lbs of salt. Seawater is then passed through the pipe 48 at 100 lbs/min, the proportion of salt included in this flow being 10 lbs. Thus in the pipe 38 to be delivered to the tubes 14 and the lagoon 10 there is 1100-100 = 1000 lbs/min of seawater including 110-10 = 100 lbs of salt, this being the flow requirement.

As the inlet end of the pipe 44 is a high temperature point and as the temperature of the seawater is increased before being transferred into the pipe 48, a flow rate could be selected which will prevent too much dumping of heat energy. It is envisaged that the heat energy contained in the seawater in the pipe 48 can be utilised by being arranged to have a heat exchange relationship with the incoming seawater in the pipe 44. As the inlet end of the pipe 44 is at relatively high temperature this minimises any cooling effect the seawater would otherwise have by being introduced into the flow circuit.

Thus there can be provided a continuous maintenance of the salinity level in the apparatus by means of this self balancing arrangement which requires no power additional to that already required by the desalination apparatus itself. Also as the arrangement is continuously operating there are no abrupt temperature changes occurring in the lagoon 10 which would be otherwise occasioned by pumping seawater into the reservoir only when required by the change in salinity level.

In a modification the solar collecting arrangement defined by the tubes 14 may be dispensed with and the lagoon 10 formed as a non-convecting solar pond. Such a pond is stratified with a low salinity layer on top of a high salinity layer such that sunlight can pass through the upper layer and be converted into heat energy in the lower layer, but a thermal barrier is defined by the junction of the two layers so as to prevent heat from escaping from the pond by means of convection. This arrangement is particularly suitable for the apparatus according to the invention wherein the salinity level can be predetermined as a multiple of the normal salinity level in the seawater.

The interface between the two layers may be further defined by a membrane stretched across the pond on the top of the lower layer, such a membrane being formed of a transparent material, for example plastics. The inlet to the pond and the outlet from the pond would communicate with the lower layer and at the inlet a baffle arrangement could be provided to ensure distribution of the incoming seawater throughout the lower layer.

Various modification may be made without departing from the invention. The tubes 14 may be formed of ultra-violet inhibited plastics material and can in fact be transparent.

CLAIMS

1. Apparatus for use in the desalination of seawater, said apparatus comprising means for transferring seawater from a reservoir arrangement, effecting evaporation of the seawater, and passing the evaporated water to heat exchange means so as to effect condensation of the evaporated water, and means for delivering seawater remaining in the evapoating means into the reservoir arrangement for heating therein by solar energy.

2. Apparatus according to Claim 1, wherein the means for transferring seawater from the reservoir arrangement and effecting evaporation comprises a vacuum boiler having an inlet communicating with the seawater in the reservoir arrangement, a steam outlet communicating with the heat exchanger means, and a further outlet communicating with the seawater delivery means.

3. Apparatus according to Claim 1 or 2, including means for including means for continuously maintaining the salinity balance in the seawater delivered into the reservoir arrangement.

4. Apparatus according to Claim 3, wherein the means for maintaining the salinity balance comprises a flow circuit defined by first conduit means connected between an outlet of the heat exchange means and an upstream side of a pump provided for removing the seawater remaining in the evaporating means, and second conduit means connected between the downstream side of the pump and an outlet, means being provided in each conduit means for controlling flow of seawater therein in accordance with the rate of evaporation, such that the salinity balance is maintained without any additional power consumption.

5. Apparatus according to Claim 4, wherein the second conduit means is arranged in heat exchange relationship with the first conduit means.

6. Apparatus according to any of the preceding claims, wherein the means for delivering seawater into the reservoir arrangement comprises a flow arrangement for collecting solar energy, the flow arrangement comprising elongate flexible conduit means arranged to be located on a terraced support surface which slopes in a direction towards the reservoir arrangement, at least the surface of the conduit means arranged to be adjacent to the support surface having heat absorbing properties.

7. Apparatus according to Claim 6, wherein the conduit means comprises a plurality of tubular elements formed of a flexible material and extending substantially parallel to one another.

8. Apparatus according to Claim 7, wherein the tubular elements are formed of a dense black plastics material, or an ultra violet inhibited plastics material or a transparent plastics material.

9. Apparatus according to claim 7 or 8, wherein the tubular elements are located within a main tubular member which is formed in two parts releasably connected together.

10. Apparatus according to Claim 9, wherein one part of the main tubular member defining the surface arranged to be adjacent to the support surface is formed of a dense black plastics material the other part being formed of a transparent ultra violet inhibited plastics material.

11. Apparatus according to any of the preceding claims, wherein the reservoir arrangement has a lining of a dense black plastics material and a transparent bubbled plastics material across the surface thereof.

12. Apparatus according to any of Claims 1 to 5, wherein the reservoir arrangement comprises a non-convecting solar pond which is stratified with a high salinity layer of seawater maintained below a low salinity layer of seawater, with an inlet to, and an outlet from the reservoir arrangement communicating with the lower layer, such that solar energy can pass through the upper layer and be collected in the reservoir arrangement while convected heat energy is prevented from passing out through the upper layer.

13. Apparatus according to Claim 12, wherein a transparent membrane is extended across the reservoir arrangement to define a physical barrier between the layers, and the reservoir arrangement has a black material surface.

14. Apparatus according to any of the preceding claims wherein power generating means is provided in the path of the evaporated water and generated power is utilised to drive all driven components of the apparatus.

15. A method of effecting desalination of seawater, said method comprising forming a lagoon in the ground as a reservoir for seawater which can be heated by solar energy, effecting evaporation of seawater removed from the reservoir condensing the evaporated water and removing the condensate, and returning the remaining water into the reservoir.

16. A method according to Claim 15, including continuously maintaining the salinity balance in the seawater returned to the reservoir without any additional power consumption.

17. A method according to Claim 16, wherein the salinity balance is continuously maintained by providing a flow of seawater through first conduit means connected between an outlet of an arrangement for the condensing of the evaporated water and an upstream side of a pump for removing the remaining water for return to the reservoir, and providing a flow of seawater through second conduit means connected between the downstream side of the pump and an outlet, and controlling the flow in each conduit means in accordance with the rate of evaporation.

18. A method according to Claim 17, wherein the salinity level in the reservoir is maintained at a predetermined multiple of the salinity level in the first conduit means by effecting the same rate of flow in the second conduit means as the rate of evaporation.

19. Apparatus for use in the desalination of seawater substantially as hereinbefore described with reference to the accompanying drawings.

20. A method of effecting desalination of seawater, substantially as hereinbefore described with reference to the accompanying drawings.

21. Any novel subject matter of combination including novel subject matter herein disclosed,

whether or not within the scope of or relating to the same invention as any of the preceding claims.

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